

Laid-Open Number : 61-267734
Laid-Open Date : November 27, 1986
Application Number : 60-110667
Application Date : May 23, 1985
Int. Class Number : G02F 1/133, G09F 9/35
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Specification

1. Title of Invention:

Liquid crystal electro-optical device

2. Claim

A liquid crystal electro-optical device controlling light scattering states of a liquid crystal panel consisting of two substrates opposed to each other with a ferroelectric liquid crystal composition interposed therebetween, by applying an electric field to said liquid crystal panel, wherein the liquid crystal electro-optical device has an active matrix driving means.

3. Detailed Description of the Invention

[Industrial Field of Application]

The present invention relates to enhancement of an information content of a liquid crystal electro-optical device which utilizes a scattering phenomenon of a ferroelectric liquid crystal composition.

[Summary of the Invention]

The present invention realizes the representation of a high information content by providing an active matrix driving means in a liquid crystal electro-optical device which controls light scattering states of a ferroelectric liquid crystal composition by an applied electric field.

[Prior Art]

An electro-optical effect [hereinafter referred to as FLS (Ferroelectric Liquid Crystal Scattering) effect] which controls the light scattering states of a ferroelectric liquid crystal has been observed to be driven in a single cell as described in Ferroelectrics, 59 (pp.145-160,

1984).

[Problems that the Invention is to Solve]

However, since the FLS effect has no distinct threshold in the above described conventional technology, there has been no choice but to combine a plurality of display elements that are statically driven for the representation of the information, therefore it has been impossible to represent a high information content.

The present invention is to solve this problem, and its object is to provide a liquid crystal electro-optical device which applies the FLS effect to the representation of a high information content.

[Means for Solving the Problems]

A liquid crystal electro-optical device according to the present invention is characterized in that it has an active matrix wherein a switching element is disposed for each display element as a driving means for a liquid crystal panel utilizing the FLS effect.

[Operation]

The present invention drives the FLS effect which is only possible in the operation by a single cell, by an active matrix. The active matrix has a switching element for each pixel, and even with a short selection time, it can be driven by the switching element disposed for the each pixel with a duty ratio close to 100%. Therefore, a liquid crystal electro-optical device using the FLS effect, which is capable of representing a high information content is realized.

Hereafter, the present invention is explained in detail according to embodiments.

<Embodiment 1>

Embodiment 1 is an example of the FLS effect panel using TFTs (thin film transistors) as active matrix elements.

Fig. 1 is a perspective view of a part of it taken out. It is configured so as that a pixel electrode (1) and a TFT (2) are provided corresponding to each pixel, and a ferroelectric liquid crystal composition (5) is interposed between them and a common electrode (4) on an opposed substrate (3).

In a case of the present embodiment, the TFT (2) is a polysilicon TFT on a quartz glass substrate, which has been formed in the same manner as those used for commercial active matrix type liquid crystal pocket televisions. It is also the same for other constituent members.

For the ferroelectric liquid crystal composition (5) in the case of the present embodiment, a rubbing treatment of organic films has been performed on the substrates as an alignment layer treatment, using BOBAMBC. A gap between the panels is $2\Delta\mu\text{m}$. The gap is adequately selected according to a required extent of the scattering and a driving voltage.

Also, even with the same gap, it is also effective to form the pixel electrode (1) or the common electrode (4) as an optically reflective electrode such as metal thin film electrode of aluminum or silver for example, to double a light path to obtain stronger light scattering.

Next, how it is driven is explained. Fig. 2 is a diagram showing an example of how an FLS effect TFT liquid crystal panel is driven. In the case of this embodiment, since the FLS effect of BOBAMBC is utilized, it is necessary to apply a polarity inversion voltage with a frequency of several microseconds to several tens of microseconds, and a DC voltage to the liquid crystal layer. The polarity inversion frequency depends upon a speed of molecular motion of the liquid crystal and a degree of spontaneous polarization. As for the condition of the present embodiment, an inverted electric field of 50Hz is applied, while the liquid crystal is in a chiral smectic phase with the liquid crystal panel being kept under a temperature of approximately 80°C . This polarity inversion electric field, as shown in Fig. 2, is made by inverting a video

gate (8) in every field (a time for addressing the entire screen of the liquid crystal panel dot-sequentially or line-sequentially) (6, 60). This is called a scattering signal (12), and is indicated as the shaded areas in Fig. 2. The common electrode (4) at this point has an electric potential near the intermediate value of that of the video signal. Therefore, an electric potential whose polarity has been inverted is written into a pixel corresponding to a scattering state in every field, so that a polarity inversion voltage which induces scattering is applied to the ferroelectric liquid crystal.

On the other hand, as for the application of a DC voltage, the video signal may be applied in every field without inverting it. It is

indicated as the portions (13) of the video signal in Fig. 2.

That is, the generation of the video signal (10) is performed so that it is selected between O_v and V_v according to display data in a signal field (60) of every two fields, and in addition, in a total-on field (6), it is performed so as that V_v or O_v is added.

Moreover, these are inverted in every N fields to prevent the degradation of the liquid crystal. It is illustrated by (14) and (15) in Fig. 2.

Although a signal for the side of a gate line (11) is omitted in Fig. 2, a pulse such as one selected sequentially is applied in the same manner as in those used in commercial pocket liquid crystal televisions. For these, refer Nikkei Electronics, September 10th (1984, p.211).

Also, for the purpose of simplification of the explanation, the video signal in Fig. 2 is a binary signal of O_v or V_v , however it may be modulated between the voltage amplitude O and V_v so as to vary the intensity of scattering. An example of the video signal in this case is shown in Fig. 3.

As described in the above, the FLS effect can be applied to the representation of a large number of pixels by the TFT active matrix driving means. Although TFTs are employed in the present embodiment, any elements as long as they are 3-terminal switching elements, are applicable. Also, in a case where a memory property remains due to interfacial alignment, it is not necessarily so required that either a DC voltage or AC voltage are always applied to the pixel electrodes.

<Embodiment 2>

Metal) diode (17) which is a 2-terminal bidirectional switching element, is used as an active matrix element.

Fig. 3 is a schematic diagram of a pixel equivalent circuit, and Fig. 4 is a perspective drawing. An MIM diode (17) is provided between a data line (18) which transfers display data and a pixel electrode (1), and is opposed to a scanning electrode (16) with a ferroelectric liquid crystal composition interposed therebetween. The equivalent circuit for one pixel is shown in Fig. 4 (b). As for the ferroelectric liquid crystal, the same DOBAMBC as in Embodiment 1 is used. The alignment treatment and gaps are also in the same manner. The MIM diode is comprised of $Ta-Ta_2O_5-Cr$, and as shown in Fig. 5, has a bidirectional

nonlinear characteristic. The manufacturing method of the MIM diode, and the configuration of the panel is the same as the ones described in Japanese Laid-open Patent No.: JP-A-55-161273, or in Proceedings of Japan Display 83 (p.404).

Next, how it is driven is explained. Fig. 6 shows an example of driving an FLS effect MIM liquid crystal panel. (a) is a data signal waveform on a data line of a third column, and similarly, (d) is a data signal waveform on a forth column, (b) and (e) are voltage waveforms applied to pixels (4, 3), (4, 4) respectively, and (c) and (f) are voltage waveforms applied to a liquid crystal layer of the pixels (4, 3) and (4, 4) respectively. Also, (g) is a scanning electrode signal waveform at a fourth row. The generation of these signals may be performed similarly as in a conventional simple matrix type liquid crystal display device.

Now, each of the signal waveforms is explained in further detail. The FLS effect requires switching of an AC voltage and DC voltage as it is also explained in Embodiment 1. In the case of the present embodiment, the driving is so configured to allow the polarity inversion in every frame (a time addressing all pixels) (19), (20). The scanning electrode signal (Fig. 6 (g)) is equivalent to a 2-frame AC method of a regular simple matrix type liquid crystal panel. The data line signals (Fig. 6 (a), (b)) are so designed to assume, alternately, the total-on frame (19) and the signal frame (20). In the total-on frame (19), it assumes an on level of the two-frame alternating current method. In the signal frame (20), when scattering, or an AC voltage, is intended, it assumes the on level (22), and when non-scattering, or DC voltage, is intended, it assumes an off level (23). The signal frame is based on the same concept as in the regular simple matrix liquid crystal

applied to the pixels. Within the voltages applied to the pixel (4, 3) and the pixel (4, 4), the operations of the pixel circuits are different while (21) is being selected. The pixel (4, 3) would be newly written on the negative side in a selected period of (21) while the MIM diode in the pixel (4, 4) would remain in an off state during the selected period of (21), so that the ferroelectric liquid crystal layer would keep a voltage on the positive side. As a result, it has been made possible to modulate the DC voltage and AC voltage according to display data. In the present embodiment, the inversion frequency of frames is set at 50Hz which is same as that in Embodiment 1. Moreover, in order to prevent the degradation of the liquid crystal, all the signal waveforms of Fig. 6 may

also be inverted in every N fields, and an inverted DC voltage may be applied.

While the above description was made for the case of binary representation for easy understanding, gray-scale representation is also possible. This is achieved by modulating the scattering intensity level by amplitude modulation between the on level (22) and off level (23). In this case, how it is driven would be similar to that in the 3-terminal case in Embodiment 1.

As explained in the above, by employing MIM diodes as driving elements of the FLS effect as one example of 2-terminal bidirectional switching elements, representation by a large number of pixels has been realized.

<Embodiment 3>

Embodiment 3 is a case of an FLS effect liquid crystal panel using a plurality of switching elements as the driving matrix element.

The panel comprises an active matrix substrate, a ferroelectric liquid crystal composition layer and a counter substrate that are similar to those in Embodiments 1 and 2, so that further description on the constitution is omitted. Fig. 7 (a) shows a functional diagram of one pixel, and Fig. 7 (b) shows an equivalent circuit wherein two transistors are used. The selection or non-selection of the pixel is determined by a selection circuit (24), and a prior state is retained by a retaining circuit (25) until a selection signal is applied. A switching circuit (26) operates according to information retained, so that a signal applied to a pixel electrode (1) is switched. In order to accommodate these functions into one pixel, it is desirable that a number of elements is as small as

The functions of the selection circuit, the retaining circuit, the switching circuit are provided respectively by a selection transistor (27), a retaining capacitor (28) and a switching transistor (29). (30) is a DC voltage source for applying the DC voltage of the FLS effect, and (31) is an AC voltage source for applying the AC voltage to the ferroelectric liquid crystal layer.

Next, how it is driven is briefly explained. At a source line (7) and a gate wiring, an addressing pulse for pixel selection is applied, and those pixels are selected once upon every one-frame generation. Display information at a selected time is given as a voltage to the retaining capacitor (28) from the source line, and the retaining capacitor

holds the information until a next selection occurs. The behaviors up to this point are performed in the same manner as in the 3-terminal switching active matrix of Embodiment 1. Next, the switching transistor (29) is controlled in its gate voltage by the voltage of the retaining capacitor (28), and switched on and off. To a source of the switching transistor (29), the AC voltage source and DC voltage source are connected via the liquid crystal layer and a common electrode (4). An on resistance and off resistance of the switching transistor are designed so as to have equivalent parallel resistance of the liquid crystal layer between them, and oscillation cycle of the AC voltage source is shorter than a parallel equivalent time constant, and its amplitude is set to be larger than the voltage of the DC voltage source. By this, as the switching transistor switches on and off, the majority of the DC voltage and the AC voltage becomes a liquid crystal layer application voltage (32) while in an on state as shown in Fig. 8 (a), and since the amplitude of the AC voltage is larger than that of the DC voltage, a sufficient AC voltage for the scattering of the FLS effect is applied to the liquid crystal layer. While in an off state, as shown in Fig. 8(b), the majority of the AC component becomes a switching transistor application voltage (33), so that the DC voltage component is applied to the liquid crystal layer. In this way, by taking advantage of the impedance of the liquid crystal layer, a simple 2-transistor configuration realizes the switching of AC and DC voltages which FLS effect requires.

An actual matrix element is configured by TFTs or MOS transistors formed on an Si substrate in the same manner as in Embodiment 1. Also, these pixel selection methods are performed equivalently to that in the liquid crystal pocket television which is

Moreover, in order to prevent the degradation of the liquid crystal, the polarity of the DC voltage source (30) may be inverted in every N fields, allowing AC driving in every N fields.

[Effect of the Invention]

As explained heretofore, by driving the FLS effect by an active matrix, an electro-optical device which has a large number of pixels that have superior property of the FLS effect, and capable of corresponding to a high information contents, can be realized.

4. Brief Description of the Drawings

Fig. 1 is a perspective view of an FLS effect TFT liquid crystal panel.

Fig. 2 is a diagram showing the driving mechanism of the FLS effect TFT liquid crystal panel.

Fig. 3 is a diagram of a video signal whose amplitude has been modulated.

Fig. 4 (a) is an equivalent circuit diagram of an FLS effect MIM liquid crystal panel.

Fig. 4 (b) is a perspective view of the FLS effect MIM liquid crystal panel.

Fig. 5. is a graph showing current-voltage characteristic of the MIM.

Fig. 6 is a diagram of a driving waveform of the FLS effect MIM liquid crystal panel.

Fig. 7 (a) is a functional diagram of one pixel.

Fig. 7 (b) is a diagram of an equivalent circuit with two transistors.

Fig. 8 (a) and (b) are diagrams of voltage waveforms applied to the liquid crystal layer and the transistor.

[Description of the Reference Numerals]

1: pixel electrode, 2: TFT, 4: common electrode, 5: ferroelectric liquid crystal composition, 17: MIM, 24: selection circuit, 25: retaining circuit, 26: switching circuit

TSM
FIC

⑩ 日本国特許庁(JP)

⑪ 特許出願公開

⑫ 公開特許公報(A)

昭61-267734

⑬ Int.Cl.⁴

G 02 F 1/133

識別記号

1 1 8

1 2 9

庁内整理番号

D-8205-2H

F-8205-2H

D-7348-2H

B-7348-2H

6810-5C

⑬ 公開 昭和61年(1986)11月27日

G 09 F 9/35

審査請求 未請求 発明の数 1 (全6頁)

⑭ 発明の名称 液晶電気光学装置

⑮ 特 願 昭60-110667

⑯ 出 願 昭60(1985)5月23日

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明 細 書

1. 発明の名称 液晶電気光学装置

2. 特許請求の範囲

相対する2枚の基板間に強誘電性液晶組成物を挟持して成る液晶パネルに、電界を印加し該液晶

において、アクティブマトリクス駆動手段を有することを特徴とする液晶電気光学装置。

3. 発明の詳細な説明

〔産業上の利用分野〕

本発明は強誘電性液晶組成物の散乱現象を利用した液晶電気光学装置の高情報量化に関するものである。

〔発明の概要〕

本発明は強誘電性液晶組成物の光散乱状態を印加電場により制御する液晶電気光学装置において、アクティブマトリクス駆動手段を設置したことに

より、高情報量の表現を可能にしたものである。

〔従来の技術〕

強誘電性液晶の光散乱状態を印加電場によつて制御する電気光学効果(以下、Ferroelectric Liquid Crystal Scattering 効果、F L S 効果と称する)は、Ferroelectrics 59, P. 145~160, 1984 に記述されるように、単一セルに

〔発明が解決しようとする問題点〕

しかし、前述の従来技術ではF L S 効果が明瞭なしきい値をもたないため情報表現に対して、スタチック駆動された表示エレメントを複数個組合せる他なく、高情報量の表現は不可能であつた。

本発明はこのような問題点を解決するもので、その目的とするところは、F L S 効果を高情報量表現に応用した液晶電気光学装置を提供することにある。

〔問題点を解決するための手段〕

本発明の液晶電気光学装置は、F L S 効果を用いる液晶パネルの駆動手段としてスイッチング素

マトリクス駆動手段により多画素の表示に応用することが可能となつた。本実施例はTFTを採用した例であるが、同様な3端子スイッチ素子であれば応用可能である。また界面配向によるメモリー性などが残る場合は必ずしも画素電極に直流電圧と交流電圧のいずれかが常に印加されている必要はない。

実施例2

実施例2はアクティブマトリクス素子として2端子双方向性スイッチング素子であるMIM(金属-絶縁体-金属)ダイオード⑩を用いた場合である。

第3図は画素等価回路図、第4図は斜視図である。MIMダイオード⑩は表示データを転送するデータ線⑨と画素電極⑪の間に設けられ、強誘電性液晶組成物⑫を挟んで走査電極⑭が対している。この一面素分の等価回路を(b)に示した。強誘電性液晶は実施例1と同じDOBAMBICを用いた。配向処理、ギャップも同一である。MIMダイオードは $Ta-Ta_2O_5-Cr$ から成り、第5図に示すよう

ルの2フレーム交流方式と同等である。データ線信号(第6図(a),(b))は、全ONフレーム⑬と信号フレーム⑭を交互にとるようになつている。全ONフレーム⑬では、2フレーム交流方式のONレベルをとる。信号フレーム⑭では、散乱つまり交流電圧とする場合はONレベル⑮、非散乱すなわち直流電圧とする場合はOFFレベル⑯をとる。

リクス液晶パネルと同じ考え方である。このようにして画素には第6図(b),(c)に示す電圧が印加される。画素(4,3)、画素(4,4)に加わる電圧で画素回路での作動が異なるのは、⑮の選択期間である。画素(4,3)は⑮の選択期間に負側に新たに書き込まれるのに対し、画素(4,4)は⑮の選択期間にMIMダイオードOFFしたままであり、強誘電性液晶層は正側の電圧を保持し続ける。この結果直流電圧と交流電圧の表示データに従つた変調が可能となつた。本実施例ではフレームの反転周波数は実施例1と同じく50Hzとした。また液晶の劣下を防止するためにNフィ

な双方向性の非型特性を有している。MIMダイオードの製造法、パネル構成は、特開昭55-161273やProceedings of JAPAN DISPLAY '83 P.404 に記述されるものと同等である。

次に駆動について説明する。第6図はFLS効果MIM液晶パネルの駆動例を示している。(a)は3列目のデータ線上のデータ信号波形、(d)は同じく4列目のデータ信号波形、(b),(c)はそれぞれ画素(4,3)、(4,4)に加わる電圧波形、(e)(f)はそれぞれ画素の液晶層(4,3)、(4,4)に加わる電圧波形を示している。また(g)は、4行目の走査電極信号波形である。これらの信号発生は従来の単純マトリクス型液晶表示装置と同様に進行することができる。

ここで各信号波形について詳しく説明する。

FLS効果は実施例1でも述べたように交流電圧と直流電圧の切換が必要である。本実施例の場合、フレーム(全画素をアドレスする時間)⑬、⑭毎に極性反転が可能とする駆動とした。走査電極信号(第6図(g))は通常の単純マトリクス液晶パネ

ールド毎に第6図の信号波形をすべて反転し、反転した直流電圧の印加をすることもできる。

以上は簡単のために2直変現の場合について述べたが、階調表現も可能である。これは、散乱強度レベルの変調をONレベル⑮とOFFレベル⑯の間で振巾変調することによつて実現される。この場合の駆動は実施例1の3端子の場合と類似と

以上述べたように、本実施例は、

素子の一例としてMIMダイオードをFLS効果の駆動素子に採用することによつて、多画素の表示が可能となつた。

実施例3

実施例3は駆動マトリクス素子に複数のスイッチング素子を用いたFLS効果液晶パネルの場合である。

パネルの構成はアクティブマトリクス基板と強誘電性液晶組成物層、対向基板であり実施例1、実施例2と同じであるので省略する。第7図(a)に一面素の機能ダイアグラム、第7図(b)にトランジ

スタを2個用いた場合の等価回路図を示す。選択回路⑦によつて画素の選択、非選択が決定され、保持回路⑧で次の選択信号が加わるまで前の状態が保持される。保持された情報によりスイッチ回路⑨が働き、画素電極①に印加される信号が切換えられる。これらの機能を1画面中に収めるために集積はできるだけ少ないことが望ましい。第7図(b)はそのための簡単な実施例の回路を示す。選択回路は選択用トランジスタ④、保持回路は保持用キャパシタ⑤、スイッチ回路はスイッチングトランジスタ⑥によつて機能している。④はF L S効果の直流電圧を印加するための直流電圧源、⑤は強誘電性液晶層に交流電圧を印加するための交流電圧源である。

次に簡単に動作を説明する。ソース線②とゲート配線には画素選択のためのアドレッシングパルスが印加され、一画面の生成毎に1回当該画素が選択される。選択された際の表示情報は、ソース線から保持用キャパシタ⑤に電圧として与えられ、保持用キャパシタは次の選択まで情報を保持して

インピーダンスを利用することによつて、簡単な2つのトランジスタ構成でF L S効果に必要な交流に直流電圧の切換が可能となつた。

実施例のマトリクス素子は、実施例1と同じくT F Tや、Si基板上に形成されるM O Sトランジスタによつて構成される。またこれらの画素選択素子は、

行なっている。さらに液晶の劣化を防止するために、Nフィールド毎に直流電圧源④の極性を反転し、Nフィールド毎の交流駆動としてもよい。

(発明の効果)

以上述べたように本発明によれば、F L S効果をアクティブマトリクスによつて駆動することによつて、F L S効果の優れた特性を持つ多画素有した高情報量対応の電気光学装置を実現できる。

4. 図面の簡単な説明

第1図はF L S効果T F T液晶パネルの斜視図。

第2図はF L S効果T F T液晶パネルの駆動図。

いる。ここまでの動作は実施例1の3端子スイッチングアクティブマトリクスと同じように行なわれる。次にスイッチングトランジスタ⑥は保持用キャパシタ⑤の電圧によつてゲート電圧が制御され、O N - O F Fする。スイッチングトランジスタ⑥のソースには液晶層、共通電極④を通して交流電圧源と直流電圧源がつながれている。スイッチングトランジスタのO N抵抗とO F F抵抗は液晶層の等価並列抵抗をはさんで設計され、交流電圧源の発振周期は液晶層の並列等価時定数より短く、またその振巾は直流電圧源の電圧よりも大きく設定されている。このためスイッチングトランジスタのO N - O F Fに伴い、第8図(a)に示すようにO N時には直流電圧と交流電圧のほとんどが液晶層印加電圧③となり、交流電圧の振巾が直流電圧より大きいため、液晶層にはF L S効果の散乱に十分な交流電圧がかかる。O F F時には第8図(b)に示すように、交流成分の大部分はスイッチングトランジスタ印加電圧③となり、液晶層には直流電圧成分が印加される。このように液晶層の

第3図は振巾変調した場合のビデオ信号図。

第4図(a)はF L S効果M I M液晶パネルの画素等価回路図。

第4図(b)はF L S効果M I M液晶パネルの斜視図。

第5図はM I Mの電流-電圧特性図。

形図。

第7図(a)は1画素の機能ダイアグラム図。

第7図(b)は2トランジスタによる等価回路図。

第8図(a), (b)は液晶層とトランジスタに印加される電圧波形図。

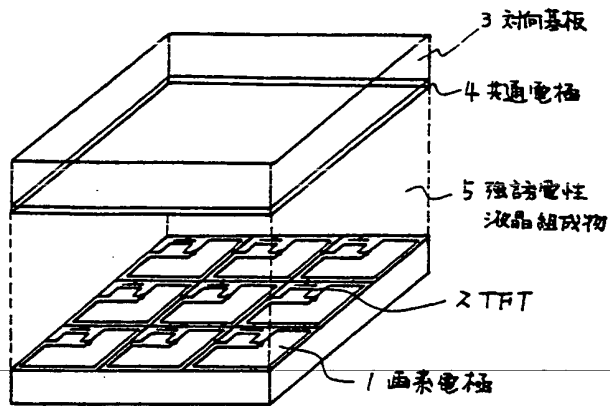
- 1…画素電極
- 2…T F T
- 4…共通電極
- 5…強誘電性液晶組成物

17…M I M

24…選択回路

25…保持回路

26…スイッチ回路



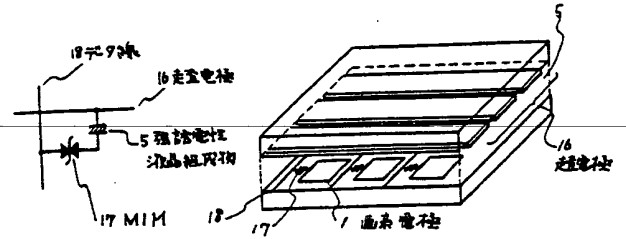
FLS効果TFT液晶
パネルの斜視図

第1図



振巾変調した場合の
ビデオ信号図

第3図

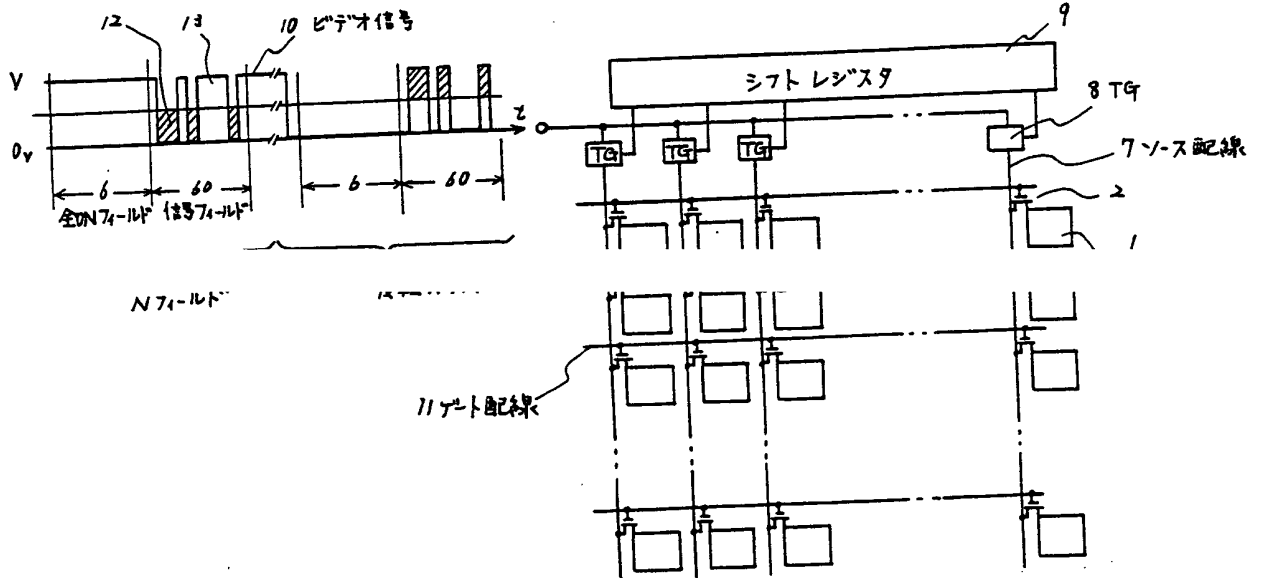


FLS効果MIM液晶パネル
の画素等価回路図

第4図(a)

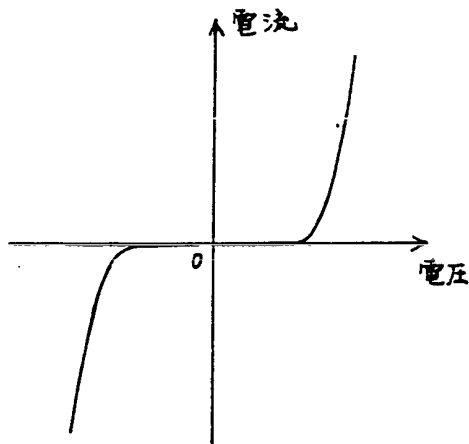
FLS効果MIM液晶
パネルの斜視図

第4図(b)



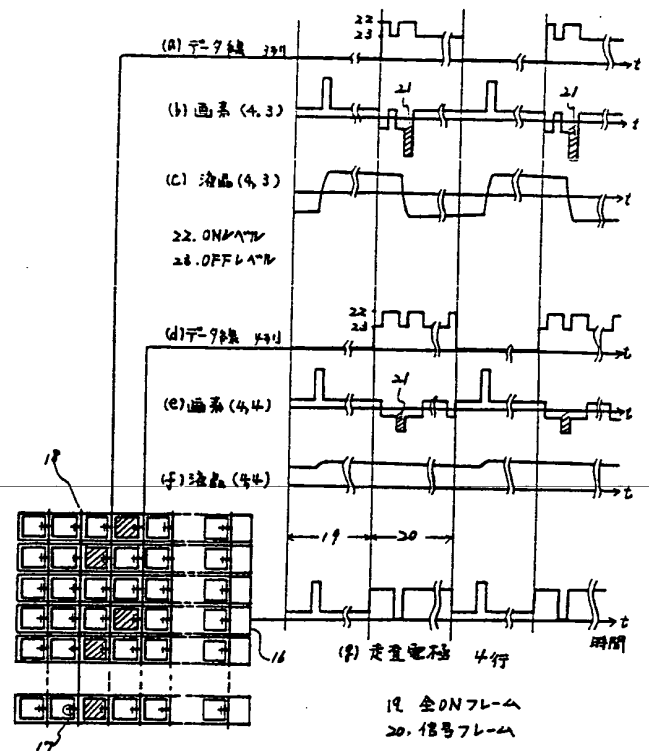
FLS効果TFT液晶パネルの駆動図

第2図



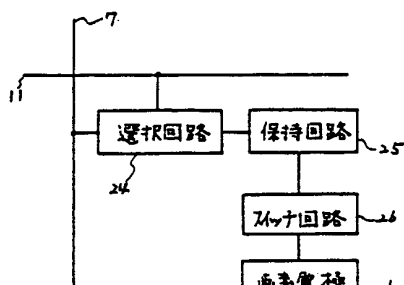
MIMの電流-電圧特性図

第5図



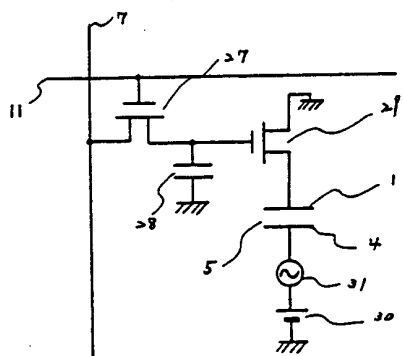
FLS効果 MIM液晶
パネルの駆動波形図

第6図



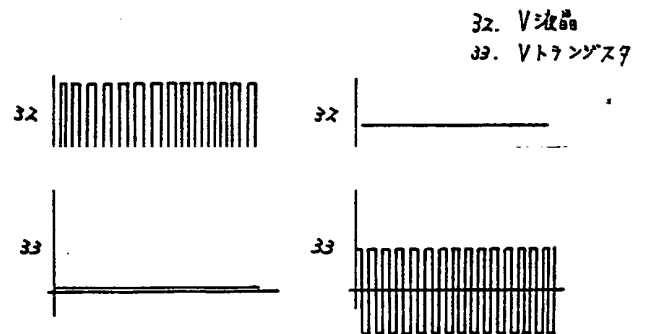
1画素の機能ブロック図

第7図(a)



2トランジスタによる等価回路図

第7図(b)



液晶層トランジスタに
印加される電圧波形図
第8図(a)

液晶層トランジスタに
印加される電圧波形図
第8図(b)